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Cover Photography by Gregory Thorp

Member Companies and Plant Locations

ADM Corn Processing
(A division of Archer Daniels Midland Company)
P.O. Box 1470 Decatur, Illinois 62525
Plants: Cedar Rapids, Iowa 52404
Clinton, Iowa 52732
Decatur, Illinois 62525
Montezuma, New York 13117

American Maize-Products Company
250 Harbor Plaza Drive
Box 10128
Stamford, Connecticut 06904
Plants: Decatur, Alabama 35601
Dimmitt, Texas 79027
Hammond, Indiana 46320

Cargill, Incorporated
P.O. Box 9300
Minneapolis, Minnesota 55440
Plants: Cedar Rapids, Iowa 52406
Dayton, Ohio 45413
Eddyville, Iowa 52553
Memphis, Tennessee 38113

CPC International Inc.
International Plaza
P.O. Box 8000
Englewood Cliffs, New Jersey 07632
Plants: Argo, Illinois 60501
Stockton, California 95206
Winston-Salem, North Carolina 27107

Minnesota Corn Processors
P.O. Box 1236
Marshall, Minnesota 56258
Plant: Marshall, Minnesota 56258

National Starch and Chemical Corporation
10 Finderne Avenue
Bridgewater, New Jersey 08807
Plants: Indianapolis, Indiana 46221
North Kansas City, Missouri 64116

Penford Products Company
(a division of PENWEST)
P.O. Box 428
Cedar Rapids, Iowa 52406
Plant: Cedar Rapids, Iowa 52406

A. E. Staley Manufacturing Company
(a subsidiary of Tate & Lyle, PLC)
P.O. Box 151
Decatur, Illinois 62525
Plants: Decatur, Illinois 62525
Lafayette, Indiana 47905 (2)
Loudon, Tennessee 37774

Board of Directors

William H. Powell, Chairman
National Starch and Chemical Company

H. Thomas Reed, Vice Chairman
Penford Products Company

Martin L. Andreas
ADM Corn Processing

John G. Reed, Jr.
ADM Corn Processing

Patric J. McLaughlin
American Maize-Products Company

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American Maize-Products Company

E. S. Micek
Cargill, Incorporated

Michael A. Urbanic
Cargill, Incorporated

Paul E. Grunder
CPC International Inc.

Samuel C. Scott
CPC International Inc.

Richard Jurgenson
Minnesota Corn Processors

Robert Nerhus
Minnesota Corn Processors

James A. Kennedy
National Starch and Chemical Corporation

Kenneth W. Kirby
Penford Products Company

Douglas A. Lapins
A. E. Staley Manufacturing Company

J. P. Mohan
A. E. Staley Manufacturing Company

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Clinton Corn Processing Company

C. G. Caldwell
National Starch and Chemical Corporation

R. S. Fisher
Hubinger

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CPC International Inc.

G. M. Mitchell
Cargill, Incorporated

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A. E. Staley Manufacturing Company

Paul E. Ramstad
American Maize-Products Company

A. M. Robinson
Hubinger

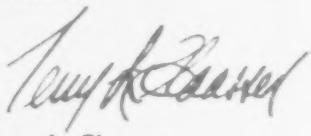
Foreword

The 1991 *Corn Annual* focuses on the diversity of the U.S. corn refining industry. USDA statisticians reported earlier this year that we purchased 13 percent of the corn grown by American farmers in 1990. That number will continue to grow as the eight members of this association continue to advance various unique product horizons each has identified.

While CRA companies compete vigorously in markets for common refined corn products, many also have a special niche on which they concentrate new product development efforts. This year alone will see dramatic advances in new plastics, further enhancements in the utility of corn sweeteners, and the creation of whole new frontiers in biochemicals—all the results of creative energy spawned by diversity.

Thus the 1991 *Corn Annual* highlights differences in "who we are." By now you may have noticed yet another such difference: a new picture on this page. Under the able leadership of CRA Chairman Bill Powell, 1991 marks a transition for the association's staff. After 25 years which have witnessed industry progress typically not seen in entire centuries, Bob Liebenow has undertaken a well-earned, although characteristically very active, retirement.

As much as may be said about this industry's capacity for progress must also be said about the contribution of the CRA, under Bob's leadership, to its successes. With the assistance of an extraordinarily skilled staff, I look forward to the challenge of continuing that tradition.



Terry L. Claassen
President

Refining Success Reflects Industry Diversity

by William H. Powell
Chairman, Corn Refiners Association, Inc.

This year U.S. corn refining will pass another benchmark: transforming one billion bushels of corn into starches, sweeteners, oil, feedstuffs and alcohol. Like the four-minute mile years ago, reaching that one billion bushel mark represents an epic achievement for our industry. And, we have the added satisfaction of hitting the mark when we predicted—at the beginning of the 1990s.

We have not succeeded through any single breakthrough, but with a wide variety of industry achievements. In the last decade, we've seen new markets and technological advances for starches, for long-established sweeteners like dextrose, for the newer high fructose sweeteners, and for ethanol. Expansion in all of these categories has produced an over-all surge in refining activity.

This diversity stands as a keystone of the U.S. refining industry. Analysts have long noted how the variety of products derived from corn represents a strength. Unlike other industries, we don't depend on a single product for success.

In fact, the diversity of corn refining goes far beyond the list of what we produce. From corporate structure to markets served, from plant size to location to product mix, the refining industry presents a study in diversity. No one succeeds in our business by copying a standard blueprint.

Rather, success in this highly competitive arena depends upon solving a complex matrix of business and technical challenges. The eight member companies of CRA have done so by developing eight strikingly individual versions of the "right" way to be a corn refiner.

Nor can a successful company rest on its laurels, repeating the same solution year after year. The issues change, and the "right" way to process corn last year may not work next year. Refining is a dynamic field in which solving one equation only leads to the next set of challenges.

So, while glad to have met the billion bushel challenge, the industry continues to move on. Where will it expand next?

Some options have gained a great deal of attention. Others, particularly in areas like modified starches, have not had as much publicity. Still others exist only in the imagination of the few researchers who sense their promise.

As high fructose corn syrup held the limelight in the late 1970s and early 1980s, ethanol currently enjoys the most publicity. Like other corn products, it offers diverse benefits and holds phenomenal growth potential.

Ethanol first gained attention during the 1970s as a fuel extender. Critics predicted it would disappear when the energy crisis eased; instead its use has grown. Another boost came with the lead phase-out, because of ethanol's octane boosting effect.

The latest increase grows out of recognition that ethanol makes motor fuel burn cleaner, helping to control pollution problems like carbon monoxide. In all, wet milling of corn for ethanol has increased over a thousandfold since those critics' predictions. Even so, ethanol has not reached its full potential. As it gains acceptance outside the Corn Belt, we can expect another major expansion by the refining industry.

Plastics from corn have also garnered a great deal of publicity recently, not all of it favorable. Starch-based degradable plastics may never solve all aspects of our nation's complex waste disposal problem, but they stand poised to make a significant contribution

and to offer refining a substantial new market.

It will take time for refiners to explore all the potential of starch-based plastics and time for these new products to grow into their proper market niches. We in the refining industry remain confident, however, that starch-based plastic technology has a very big future.

Corn sweeteners also have outstanding potential to develop in an entirely new direction. Many people assume sweetness is the only selling point for corn sweeteners. In fact, they offer a variety of useful technical properties, one of which—their value as fermentation feedstocks—may be the next avenue of development for these diverse products.

The exciting potential of chemicals from corn, which we discussed in the *Corn Annual* ten years ago, has moved closer to reality with the blossoming of the U.S. biotechnology industry. Corn refiners face an increased demand for products like glucose and dextrose to make citric acid, lysine and other biochemical products.

Starches continue their growth as essential ingredients in more and more food and industrial products. Year after year, corn refiners develop and introduce new starch modifications which increase efficiency in paper making, make possible new microwavable foods, replace fats in our diets or otherwise improve our lives. Indeed, one cannot possibly enumerate all the opportunities for further industry growth in starches.

What will all this mean for corn refiners and the corn growers who supply our raw material? Economists estimate that increasing the demand for corn by 100 million bushels increases the price of corn by 15 cents per bushel. Success in even a few of the alternatives I've outlined will mean another decade of major refining industry growth and of increases in corn use, benefitting growers and refiners alike.

I can't promise which alternatives will succeed or how soon. But, I can predict that refiners will continue to find success in diversity. Ten years from now, the refining industry will be using more corn, making a wider variety of products, and proving itself ever more useful to the U.S. economy and the world.

Shipments of Products of the Corn Refining Industry—1990

Starch Products	
(Includes corn starch, modified starch and dextrins)	4,959,019,000
Refinery Products	
(Includes glucose syrup, high fructose corn syrup, dextrose, corn syrup solids, maltodextrins)	22,772,039,000
High fructose corn syrup—42%	6,796,208,000
High fructose corn syrup—55+	8,751,128,000
Total HFCS	15,547,336,000
Total—Domestic Basic Products	27,731,058,000
Total—Export Basic Products	609,806,000
Corn oil (crude and refined)	1,131,058,000
Corn gluten feed and corn oil meal	9,371,877,000
Corn gluten meal	1,782,179,000
Steepwater	306,243,000
TOTAL SHIPMENTS	40,932,221,000

Compiled for the Corn Refiners Association, Inc., by Ernst & Young. Statistics represent shipments by members of the association. Shipments are in pounds, commercial weights.

Industry Structure Defies Labels

"What's the typical set-up in corn refining?" the caller asked. The honest answer—"It depends. . ."—seems always to lead to more complexity, more explanation, than most callers bargained for..

Of the hundreds of questions the Corn Refiners Association staff fields every year, questions about what is "typical," "normal," or "average" are some of the toughest. As statisticians know, an average can misrepresent reality when the examples being averaged vary greatly. And, there's no doubt about the variety among corn refiners.

In fact, the eight member companies of the CRA offer such a diversity of structures, sizes and approaches that the industry makes a good case study of the choices possible in a free market economy.

Corporate Structure

The "typical" refining company could be publicly owned, like so many businesses, but it could also be a privately held corporation like Cargill, Incorporated—one of the largest private companies in the world.

If publicly owned, it could be a modern multinational like CPC International Inc., a foreign-owned subsidiary like A.E. Staley Manufacturing Company, or a classic example of continued family leadership like American Maize-Products Company.

A "typical" refining operation could also be an example of a new grass-roots initiative like Minnesota Corn Processors, established in 1983 and owned by the farmer-members of an agricultural cooperative.

Successful corn refining operations exist as stand-alone businesses whose sole activity is wet milling, as divisions of giant commodity trading corporations, and as components in classic corporate conglomerates. And, just as corporate structures vary, so do business structures, and even plant conformations.

Business Structure

Whether it's establishing a new plant or expanding into a new market, every business move a refining company makes requires a series of critical decisions. And, each company seems to find its own creative method of combining raw material availability, transportation and access, markets and demographics.

Domestically, some companies are "cornfield based," locating their plants in the Midwest, drawing support and user industries to them in cities like Cedar Rapids, Iowa, and shipping products out to the great population centers.

Other companies have chosen a more "customer based" approach. While operating facilities in the Corn Belt, companies like American Maize-Products and CPC International have also sited plants near major markets. "Customer-based" companies ship raw grain to locations like Stockton, California; Decatur, Alabama; and Winston-Salem, North Carolina, to process it near major markets on the West Coast, in the South and on the East Coast.

On an international level, the diversity is even greater.

International Structures

Despite restrictions that prevent the full development of corn refining in many nations, corn refiners are active throughout the world. Their efforts to adapt their foreign operations to regulations that vary from country to country have, again, produced a diversity of solutions to business problems.

Foreign operations include wholly owned subsidiaries, like Cargill's plant in Great Britain. In other countries, including Korea and much of South America, joint ventures have proved successful.

Refiners also work with independent foreign corn processors, supplying operating services and expertise. In other instances, refining companies develop technology agreements and license technology to foreign processors.

While the U.S. refining industry is the largest and most successful, corn refining has taken root in almost 50 other countries around the world. In some countries, notably Japan and Korea, refiners have developed a strong presence, increasing their use of corn and their contribution to the nation's economy.

Still, government policies, in nation after nation, create daunting barriers to the expansion of

refining and, in some cases, effectively halt any growth in corn processing or the use of corn products.

Plant Structure

As there is no "typical" corn refining company, there is also no "typical" corn refining plant. The so-called "front end," or separation steps, in the refining process is the same throughout the industry. In fact, these steps, in which the corn is processed in a water slurry, are the basis for the term "wet milling" and for determining whether a company is classified as a corn refiner. But, there the similarity stops.

Among the 24 U.S. refineries, some grind no more than 25,000 bushels of corn per day. At the opposite extreme, other plants can process several hundred thousand bushels per day.

Plant employment can range from just over 100 to well over 1,000 people. Differences in plant

Member Company Products

	ADM Corn Processing	American Maize-Products Company	Cargill, Incorporated	CPC International Inc.	Minnesota Corn Processors	National Starch and Chemical Company	Penford Products Company	A.E. Staley Manufacturing Company
Starch Products								
Unmodified, food	●	●	●	●	●	●		●
Unmodified, industrial	●	●	●	●	●	●	●	●
Modified, food		●	●			●		●
Modified, industrial	●	●	●	●		●	●	●
Dextrins	●	●				●		●
Cyclodextrins		●						
Refinery Products								
Glucose syrups	●	●	●	●	●		●	●
Maltodextrins		●					●	●
Dextrose monohydrate	●			●				●
Dextrose anhydrous				●				
HFCS-42	●	●	●	●				●
HFCS-55	●	●	●	●				●
Crystalline fructose	●							●
Co-Products								
Crude oil	●		●					●
Refined oil	●		●	●				●
Corn gluten feed	●	●	●	●	●	●	●	●
Corn gluten meal	●	●	●	●	●	●	●	●
Corn germ or corn germ meal	●	●	●	●	●	●	●	●
Steepwater (CFCE)		●	●	●	●	●		●
Carbon dioxide	●							●
Other								
Ethanol, fuel/industrial	●			●	●			●
Ethanol, beverage	●							
Fermentation and other chemicals	●		●					

Product lists are accurate as of publication date but may change with time.

employment are not simply a reflection of size. They also reflect the complexity of plant management based on the number of different products a plant makes and on the number and variety of customers a plant serves. The demands a refinery staff has to meet can be very different when its customers represent hundreds of small-scale users rather than a few industrial giants.

It's a mistake to think of refinery employment only in terms of the plant operations function. While precise and consistent control of the milling process is a refining essential, so is the research that goes into new products and better processes, the information and support that helps customers use corn products more effectively, the marketing that promotes refined products around the globe, and the tactical and strategic initiatives essential in corporate leadership.

Nor do all refineries produce the same range of products. While all refiners recover feed coproducts,

Corn Production and Plant Locations

Over 700 million bushels per year:

- Illinois
- Indiana
- Iowa
- Minnesota
- Nebraska

200 million to 700 million bushels:

- Michigan
- Missouri
- Ohio
- South Dakota
- Wisconsin

100 to 250 million bushels:

- Colorado
- Kansas
- Kentucky
- Pennsylvania
- Texas

• CRA member company plant

the combinations of primary products seem endless.

At one extreme are plants with only one primary product—for example, ethanol. Then there are facilities like the Indianapolis and North Kansas City plants which concentrate on one category of refined corn products. While they make "only" starches, that category alone comprises a broad spectrum of products: common starch, white and yellow dextrins, British gums, acid-modified and oxidized starches, specialty starches from waxy maize or high amylose corn, starch derivatives, pregelatinized and bleached starches.

Another type of refinery benefits from "swing capacity" between two or more primary products. The Loudon, Tennessee, plant is a classic example. Designed with two primary products—high fructose corn syrup and ethanol—in mind, the Loudon plant can shift a part of the starch from the front end of the process to HFCS production during the summer, when HFCS demand is at its strongest. In winter, instead of idling some or all of its capacity, the Loudon facility can shift its focus to ethanol production.

Finally, some facilities like the Decatur plants in Illinois make a broad spectrum of refined corn products: starches, a range of sweeteners from glucose syrups to dextrose to HFCS and crystalline fructose, plus ethanol.

Products

The final products which corn refiners market provide the most concrete example of the industry's diversity. A review of CRA member companies' products demonstrates eight different approaches to success in corn refining—since no two companies have duplicate product lines.

Product diversity is, in fact, even greater than the chart indicates, since different companies offer different specific products within broad categories such as glucose syrups or modified food starches.

The Face of Success

What characteristics, then, do successful corn refiners have in common?

First, successful refiners are committed to efficiency in manufacturing quality products. The dedication to efficiency goes beyond simply preventing wasted effort or wasted resources. For decades, refiners have aggressively pursued ways to turn what once was waste into useful products and to do the job with less cost, less energy. Similarly, their dedication to quality products is more than just an effort to supply consistent, pure starch or syrup. Instead, they reach beyond the current product line, working with customers and users to develop both better versions of established products and altogether new ones.

Second, successful refiners are absorbed by the potential in new technology and scientific breakthroughs. There is little tendency to rest on yesterday's laurels. Instead, refiners search continually for new insights that realize more of the value in corn and make corn processing even more successful.

Finally, successful refiners have a deep dedication to free market competition, with its emphasis on individual initiative and creativity. As much as its involvement with corn, the distinctively American crop, it's this commitment to competition which marks refining as a classic American industry.

Refiners Serve Diverse Markets

A recent series of advertisements from one of the major corn refining companies tells its customers that they should view the firm as the "Supermarket to the World." Considering the amazing range of food products they make, this is no idle advertising statement. But, the range of markets served by today's corn refining industry goes far beyond just the grocer's shelf.

Products made with help from the modern corn refining industry may just as easily be found in the department store, the hardware store, the drug store or the gas station. The full range of end-uses for corn derived products is rightly the subject of a full exploration on its own, and interested readers should ask for a copy of the brochure "Tapping the Treasure in Corn" from the Corn Refiners Association.

Beyond the broad range of products of today's multi-billion dollar corn refining industry lies a strategy which encompasses all of the major marketing systems in use by American business today.

Today's financial press, in analyzing the strategies of American firms to compete in a new global environment, stresses the success firms have had by narrowing and defining their mission. While a well-focused mission is vital to the success of any particular firm, the corn refining industry is an excellent example of how a group of firms can, when taken together, serve a broad variety of missions.

One way of looking at the many faces of success in the corn wet milling industry is by exploring the different styles of markets which refining firms serve today. Broadly defined, these consist of commodity, specialty, consumer and export markets.

Commodity Markets

While the proper definition of commodity encompasses "anything useful that can be turned to commercial advantage," in business vernacular it has come to be associated with bulk products, manufactured for further use by other industries. And in this field, corn refiners excel.

The quantity of bulk food and industrial ingredients coming from the corn processing industry today is truly impressive. For starters, we can look at the volume of raw corn being purchased by the industry.

In 1991, analysts expect the industry to cross the one billion bushel mark in corn purchases, continuing the trend of the industry as the fastest growing single market for U.S. grain producers. In a business sector which is generally considered "mature", the four-fold growth of the industry over the past 15 years is a major accomplishment.

The biggest contributor to the industry's achievements in commodity markets is the 22.7 billion pounds of natural sweeteners produced each year. The application of technology and science to the production of this staple of man's diet has brought major cost savings to U.S. food processors, while providing them with a full range of consistently pure nutritive sweeteners.

Foremost among these is high fructose corn syrup which has become the sole sweetener for non-diet soft drinks in the U.S. In the coming years, analysts expect that starch-based sweeteners will make major inroads in most of the developed economies around the world.

The recent Persian Gulf conflict has highlighted the sway of one of the world's largest commodity markets—oil—on world events. And, while the volume of fuel alcohol produced by the corn industry pales in comparison to the world oil market, in the last decade corn refiners have begun a long process of replacing part of this dwindling commodity with a renewable resource.

The move in the U.S. toward reformulating gasoline to provide cleaner-burning fuels is expected to at least double the 800-million gallon market for fuel ethanol from corn over the next five years. In addition, commercial production of ETBE, an ethanol-derived fuel additive, is expected to begin. Between these two products, the corn industry may have a hand in as much as 20 percent of America's gasoline supply.

Finally, U.S. corn refiners have achieved a major position in the world commodity market for animal feed ingredients. Co-product feeds and meals from the wet milling process have been accepted as major ingredients of

commercial dairy, poultry, swine, cattle and pet feeds, and about six million tons of these ingredients are shipped each year.

Specialty Markets

Specialty markets are characterized by being based on a widely-available product that has been tailored to provide a specific function or application that is not provided by the broader product class. In corn refining, numerous examples of specialty markets exist across the full spectrum of the industry's production. The longest established and most prevalent case of specialty marketing by the corn refining industry is the development of starch modification technology. Starch, one of nature's most widely available compounds, can be tailored in nearly infinite ways to meet requirements of different users.

In both food and industrial applications, starch users often require formulations which are highly unique to their end products. Through the years, corn refiners have recognized that while these markets may be small in relation to the traditional commodity markets, the value added to starch through specialty modifications may more than make up for the lack of volume.

Recently, a number of corn refiners have turned their attention to specialty markets in the biochemical and pharmaceutical industries which hold great promise. Cyclodextrins, a new product from corn refining, is being tested as an encapsulating agent in many specialty applications.

In the area of biochemicals, corn refiners have made major capital investments over the past several years in production facilities for organic acids used in food and pharmaceutical products and amino acids used to upgrade the quality of animal feeds.

Specialty marketing by the corn refining industry is a major demonstration of the commitment of U.S. agriculture to go beyond its traditional role as a supplier of bulk raw materials into a new position of value-added marketing.

As America struggles to reestablish its role as the leader in international markets, the kind of value-added marketing strategy being pursued by the industry promises to bring improved employment and export earnings to the U.S. economy.

Consumer Markets

When most people think about markets, they don't naturally think of the commodity and specialty ingredient markets which comprise the majority of the corn refining industry's sales. What they think of is what is closest to them—the retail, consumer market. Even here, you'll find the

Exports of Products From Corn

Product	1990	Units
Corn meal	115,798,275	Kilograms
Corn starch	51,714,260	Kilograms
Starch NESOI*	14,542,018	Kilograms
Corn oil, crude	128,713,457	Kilograms
Corn oil, once refined	18,251,244	Kilograms
Corn oil, fully refined	56,717,589	Kilograms
Glucose in solid form and glucose syrup with below 20% fructose	61,928,528	Kilograms
Glucose syrup with 20–50% fructose	14,864,657	Kilograms
Chemically pure fructose	7,651,584	Kilograms
Fructose syrup with 50+ fructose	57,165,253	Kilograms
Fructose solids with 50+ fructose	26,765,026	Kilograms
Bran of corn	52,249	Metric tons
Corn gluten feed	5,350,278	Metric tons
Corn gluten meal	435,171	Metric tons
Other residues of starch manufacturing	19,711	Metric tons
Corn oilcake	184,527,115	Kilograms
Dextrins and other modified starches	43,176,244	Kilograms

*Not Elsewhere Specified or Included
Source: U.S. Department of Commerce

corn refining industry active and growing.

Consumer marketing requires a different organization, different skills and a different outlook than marketing commodity and specialty products. But the skills in production, distribution, consumer preference testing, promotion and advertising needed to succeed in this arena find valuable application throughout the industry.

A hundred and fifty years ago, the corn refining industry got its start in America by providing "lump starch" to household launderers. Today, although the products have been vastly improved, laundry starch from corn refiners is still a familiar product to supermarket shoppers.

Although corn oil accounts for only a small portion of the total food oil produced in the U.S., consumers consistently rank corn oil as the preferred oil for home use, and both branded and house-brand varieties of corn oil are constant best-sellers for supermarket managers.

In today's vigorous battle for supermarket shelf space corn oil's position is secure because of consumer awareness of the role of corn oil in lowered-cholesterol diets. Finally, that mainstay of the food processing industry, corn syrup, remains a staple item on supermarket shelves.

Export Markets

So far, we have focused on classes of markets served by corn refiners. But beyond these distinctions, it is important to note the industry's growing role as an exporter of U.S. agricultural products.

As America's bill for imported oil, imported automobiles and imported electronics has skyrocketed, we have come to depend on agricultural exports as a counter-balance in U.S. trade. And, while export markets for U.S. raw commodities have see-sawed with changes in world economics and

World Corn Supply and Disappearance

	1989/90	1990/91
Exports		
Argentina	3.1	3.5
South Africa	3.0	0.3
Thailand	1.4	0.8
China	3.2	5.5
United States	60.0	49.3
Others	2.7	1.1
TOTAL	73.3	60.5
Imports		
Mexico	5.0	3.5
European Community-12	3.1	4.0
U.S.S.R.	17.7	9.0
Japan	16.1	16.5
Eastern Europe	3.5	2.6
China	0.5	0.0
Taiwan	5.3	4.6
Republic of Korea	6.1	6.0
Others	16.1	14.3
TOTAL	73.3	60.5
Production		
Brazil	21.8	25.0
Mexico	9.8	12.0
Production Cont.		
Argentina	5.2	6.8
South Africa	9.2	6.0
Thailand	4.0	3.7
European Community-12	26.9	21.7
U.S.S.R.	15.3	14.0
Eastern Europe	29.8	22.6
China	78.9	88.0
United States	191.2	201.5
Others	69.3	68.5
TOTAL	461.3	469.8
Utilization		
European Community-12	29.3	26.2
U.S.S.R.	33.4	23.0
Japan	16.3	16.5
China	76.2	78.5
United States	146.0	156.7
Others	176.3	172.9
TOTAL	477.4	473.7
Ending Stocks		
Foreign	37.2	37.4
United States	34.2	30.1
TOTAL	71.4	67.4

Source: USDA Based on October/September year in millions of metric tons.
1990/91 represents a forecast total.

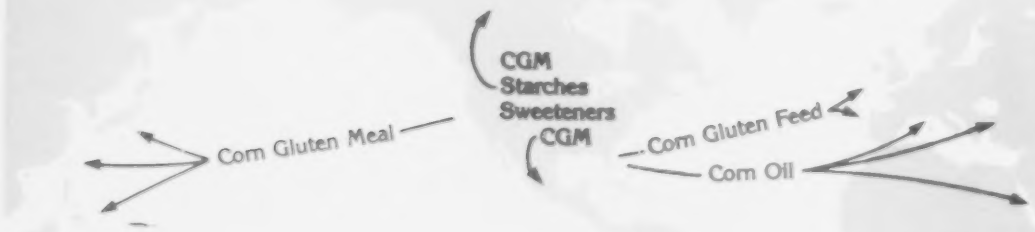
politics, markets for processed products from corn refiners have climbed steadily.

Over the past decade export shipments from corn refining have risen to over $800 million—a substantial portion of total industry output. Export earnings from value-added starches and sweeteners have tripled. U.S.-produced corn gluten feed remains one of the last items of free agricultural trade between the U.S. and the European Community. Corn gluten meal is finding new markets in the emerging Pacific Rim economies and corn oil from American refineries has become a major export to southern Europe and the Middle East.

All Things Considered . . .

No one industry can lay claim to being all things to all people. However, the modern corn refining industry is certainly many things to many people. The mix of commodity, specialty, consumer and export markets which it serves rivals those of the largest of U.S. manufacturing sectors. As new products of corn refining technology find their way into this mix, they will further strengthen the role of the industry as one of the backbones of U.S. agriculture and industry.

Major Export Markets for Refined Corn Products



Corn Refiners Push Into Biochemical Processing

Links between the corn industry and the chemicals industry are getting closer. Biochemicals production using corn-derived feedstocks continues to rise, with the prospects of some exciting growth in the near future as new biotechnology processes come of age. And 1990 and 1991 are seeing some corn refiners getting directly involved in chemicals production—in some cases pioneering corn feedstock-based production processes that could challenge traditional petrochemical-based processes.

As consumers of corn-based feedstocks, biochemicals production is dwarfed by the production of ethanol and high fructose corn syrup. According to U.S. Department of Agriculture figures, production of high fructose corn syrup consumed 380 million bushels of corn in 1989, and ethanol consumed 245 million bushels. No specific figures are available, but industry sources say biochemicals production accounted for only a small though growing part of the U.S.'s dextrose and glucose output, which consumed 200 million bushels of corn.

U.S. corn refinery shipments of dextrose have ridden steadily upward since 1986, rising 20 percent in total between 1986 and 1990. According to industry sources, dextrose shipments (excluding dextrose substrate for fuel/industrial ethanol production) rose from 490,000 short tons (dry weight) in 1986 to 550,000 tons in 1988, and 590,000 tons in 1990.

One driving force behind that has been the growing popularity of "lite" beers which use dextrose in their fermentation, but biochemicals production has made a growing contribution too. Recently the dextrose market has been tight. "We take a downgraded 95 percent solution compared to the 99 percent solution the brewers take," recounts the plant director at one organic acids fermentation plant which recently made a significant expansion. "A lot of our [feedstock] availability depends on how much beer people are drinking," he notes.

Responding to the situation, there have been some recent dextrose capacity expansion announcements by the refining industry. CPC International will increase dry dextrose capacity by 35 percent over the next two years at its Argo, Illinois, plant. Cargill has just completed a 50 percent increase in its overall U.S. milling and refining capacity, to meet increased demand for sweeteners and other corn milling products. A. E. Staley Manufacturing has just completed a polydextrose unit at Toronto and plans to build another in the U.S. in 1992, but gives no indications of expanded dextrose production. The other leading refiners have not announced whether they have added capacity.

A sampling of recent project announcements suggests that biochemicals' contribution to dextrose demand is set to rise further. In February 1990, Takeda Chemical Products U.S.A. started up a 5,500 ton per year vitamin C unit. This adds to consumption of dextrose-based sorbitol, which Takeda's unit consumes as raw material.

This year, Kodak affiliate Genencor International is due to start up its $60 million fermentation facility at Cedar Rapids, Iowa, which will produce enzymes. Genencor officials indicate enzymes production is just a beginning, and the firm plans eventually to produce a range of amino acids, vitamins, metabolites, and specialty biochemicals at the plant.

"One of the primary reasons for locating there was the availability of corn-based raw materials," says a Genencor official. Genencor is not alone in targeting enzyme production. With prospects for increased demand for enzymes in phosphate-free detergent formulations in the U.S., other enzyme producers anticipate increased output in the coming years.

Production of two corn-based chemicals invented three decades ago and commercialized by Horizon Chemical, until recently an A. E. Staley subsidiary, is about to get started. Horizon will start up a unit in third quarter 1991 at Muscatine, Iowa, to produce a family of products based on methyl glucoside, derived from modified glucose. Horizon's products are used as extenders and reactant intermediates for phenol-formaldehyde resins and polyurethane foams.

Meanwhile, Henkel Corp., the U.S. affiliate of detergents giant

Henkel (Dusseldorf, Germany), is building a 25,000 ton per year facility at Cincinnati, Ohio, to produce alkyl polyglycosides, to start up in 1992. Alkyl polyglycosides, originally developed by Horizon, are based on glucose and fatty alcohols. Henkel says alkyl polyglycoside surfactants have excellent foaming, solubilizing and grease cutting capabilities. Distinguished by mildness, nontoxicity and rapid biodegradability, Henkel says, "they ideally meet the requirements for surfactants of the future." Henkel will use them in dishwashing liquids and shampoos. Its decision to bring the product to market now reflects new opportunities Henkel perceives in the environmentally sensitive and increasingly affluent consumer market of the 1990s, comments one consultant.

On a smaller scale, Merck & Co.'s Kelco affiliate plans to spend $29 million to expand its biogum capacity at San Diego, California, and Okmulgee, Oklahoma. This expansion should increase the consumption of corn-based sweeteners, which are used as nutrients in the fermentation process. Kelco anticipates rapid growth in demand as it introduces newly developed gellan, welan and rhamsan gums to supplement its main product, xanthan gum. The new capacity is due to be in operation by the start of 1992. Austrian biochemicals producer Jungbunzlauer (Vienna) has been linked to a Corn Belt biogum project but says there is no project under evaluation at present.

Dextrose is also gaining usage from the growth in new biotechnology-derived pharmaceutical products now coming onto the market and produced by fermentation processes. Here, dextrose is able to edge out less refined substrates like molasses, used in older processes and which tend to require further purification treatment. "If you have a cloned, recombinant organism and a high margin, delicate process, you want a pure feedstock," says a refiner source. "Dextrose fits the bill very nicely there."

Consulting firm Consulting Resources (Lexington, Massachusetts) projects the market for recombinant DNA biotechnology-based pharmaceuticals (therapeutics and diagnostics) products rising from $1.2 billion per year in 1990 to $9 billion per year at the end of the decade. That is an attractive market growth rate that the dextrose industry will certainly want to get its share of. The penetration of the food and agriculture market of recombinant DNA products—many based on fermentation—is a lot slower, but Consulting Resources still forecasts growth from $55 million per year in 1990 to $2 billion per year in the year 2000.

But the really major expansions in dextrose-consuming biochemicals fermentation have been, or are being made, by the corn refining companies, as they move from being suppliers of dextrose to major biochemical

Corn: Food, Seed and Industrial Uses

Year	Wet-Milled Products				Dry-Milled Alcohol	Dry-Milled and Alkaline Cooked Products	Seed	Total
	HFCS	Glucose and Dextrose	Starch	Alcohol				
	Million bushels							
1980	165	183	120	35	35	160	20	718
1981	185	183	130	83	35	162	19	797
1982	215	188	127	130	50	170	15	895
1983	256	189	147	150	50	164	19	975
1984	310	187	143	170	100	160	21	1,091
1985	328	188	152	185	127	161	19	1,160
1986	339	185	155	200	135	161	16	1,191
1987	359	187	167	200	136	163	17	1,229
1988	362	196	164	210	133	161	19	1,245
1989	370	206	172	222	140	161	19	1,290
1990	380	210	173	235	142	161	19	1,320

Source: USDA—Economic Research Service
Year beginning Sept. 1

producers themselves. Having added value to corn through the development of the market for high fructose corn syrup and having expanded ethanol production, now it looks to be the turn of biochemicals as a way for the corn refiners to add value to their wet milling products.

In early 1990, Cargill started up a $45 million, 55 million pound per year citric acid unit at its Eddyville, Iowa, wet milling plant. Cargill hopes for "further fermentation-based product opportunities," a company representative said.

Cargill had previously only been a feedstock supplier for biochemicals production, notably supplying dextrose to Heartland Lysine, a Franco-Japanese lysine maker which had located at Eddyville. Heartland's 67 percent increase in lysine capacity to 20,000 tons per year last year has correspondingly upped its dextrose consumption. Biokyowa also increased lysine production last year, a 73 percent increase to 13,000 tons per year.

Last fall, Archer Daniels Midland started up a large scale fermentation plant at its Decatur, Illinois, site, initiating its ambitious drive into the biochemicals field. ADM projects annual sales of $500 million within two to three years in biochemicals. ADM underpinned its in-house moves by the acquisition last year of Pfizer's citric acid operations—based at Southport, North Carolina, and Ringaskiddy, Ireland—and its sorbitol production at Groton, Connecticut.

Initial production at ADM's 125-million-pounds-per-year unit is the amino acid lysine, used as an additive in poultry and swine feed. ADM has world scale ambitions: Its lysine capacity is equivalent to half of total world consumption. ADM's strategy is to capture half of the American market for lysine—equivalent to about half its output, and export the remainder.

Its method: displacing much of the import material which currently accounts for half of U.S. consumption. ADM will also compete with the subsidiaries of French and Japanese companies that account for U.S. lysine production, but which are not back-integrated with their own corn wet milling operation. ADM also says southeast Asia will be a particular focus for its exports.

In addition to lysine production, ADM has announced plans to produce the amino acids tryptophan and threonine at the same unit. ADM is also building fermentation units to produce 20 to 40 million pounds per year of lactic acid, feed grade penicillin and bactracin, and the vitamin biotin. ADM has not announced a specific date but has indicated these are to start up some time in the next twelve to eighteen months. Further out, ADM has plans to make specialty enzymes, monosodium glutamate, sodium gluconate, and Vitamin C. ADM had previously announced plans for citric acid production capacity, but these are on hold following its acquisition of Pfizer's citric acid business.

The foundation of the wet milling industry's entry to the biochemicals business is its large source of dextrose feedstock. In addition, corn refiners have built in low energy costs through their major investments in cogeneration-sourced steam and electricity plants. The industry's experience in syrup and ethanol production has provided it with experience in enzymes and fermentation as well.

Besides the scale which corn refiners can bring to the biochemicals business, competitors have been impressed with the innovative approach of the industry. As with ethanol, the industry appears intent on going head-to-head with existing domestic producers of competitive products based on petrochemical feedstocks. If successful, these pioneering firms will reaffirm the viability of the fermentation route and could even herald a new era of agricultural feedstock-based chemical production.

Ethanol, HFCS Offer Product Synergy

by Peter A. Meyer, President, PMI Consultants

The production of alcohol ranks among the oldest two or three professions. Fruit and honey and finally grain became the fermentation media of choice. Beer, wine and spirits producers were valued members of their communities. Centuries later, corn wet millers followed the dry millers into alcohol production.

By the mid-1970s, the wet millers were large suppliers of alcohol for grain neutral spirits to beverage alcohol marketers and modest suppliers to other industrial and food users. Total corn wet milling capacity for alcohol in 1977 was approximately 50 million gallons at 200 proof or 100 percent alcohol. It was just the beginning.

Fuel ethanol began as "gasohol," a gasoline extender, after one of many OPEC oil shocks. Ethanol sales advanced in response to both the need for octane enhancers to replace lead and government tax incentives, state and federal.

These incentives were born in the fervor for energy independence and matured as an alternative to government grain storage payments and/or a response to the farm crisis in many states in the early 1980s.

Legislative Background

The Energy Tax Act of 1978 exempted motor fuels containing at least 10 percent ethanol from the $.04 per gallon federal excise due on the motor fuel. In other words, each gallon of ethanol produced $.40 worth of tax forgiveness when blended with gasoline.

The Crude Oil Windfall Profit Tax of 1980 extended the exemption of the 1978 Act through 1992 and created a blender's tax credit of $.40 per gallon as an alternative to the excise tax exemption. This provided an adequate time horizon for investment decisions in ethanol facilities and an incentive to gasoline marketers.

The Highway Revenue Act of 1982 increased the excise tax on gasoline from $.04 per gallon to $.09 per gallon. This "revenue enhancement" measure was also designed to encourage conservation in the face of declining gasoline prices.

Companion legislation, the 1982 Surface Transportation Assistance Act, increased the exemption and the blenders credit from $.04 to $.05 per gallon of ethanol containing fuel effective April 1, 1983. This, of course, increased the exemption from $.40 to $.50 per gallon of ethanol.

In the Tax Reform Act of 1984, Congress increased the federal excise tax exemption from $.05 per gallon of ethanol containing fuel to $.06 per gallon effective January 1, 1985.

The hard-fought 1991 budget bill extended the exemption and credits but reduced them to $.54 per gallon of ethanol. The inferred savings were given to small producers in the form of a $.10 per gallon tax credit on the first 15 million gallons of production from a plant producing 30 million gallons or less.

This small producer credit will not be of much benefit to wet milling companies whose output tends to be larger. In addition to the extension of tax credits through the year 2000, 1990's legislative session produced a major new amendment to the Clean Air Act.

The Clean Air Act mandates several guidelines that could dramatically affect ethanol demand. All Consolidated Metropolitan Statistical Areas (CSMA) with EPA carbon monoxide designations at or above 9.5 parts per million—44 cities with gasoline consumption of 17 billion gallons—are affected.

A minimum of 2.7 percent average oxygen content must be reached in all fuel sold in non-attainment areas. If this goal is not reached by a fixed future date, a 3.1 percent oxygen content requirement must be implemented.

The amendment further mandates that gasoline must be reformulated to eliminate toxics and other volatile organic compounds and requires the use of oxygenates such as ethanol, ETBE or MTBE. The Clean Air Amendments increase the potential market for ethanol by 500 to 600 million gallons over the next five years, and an even larger market is possible if ETBE, an ethanol derivative, becomes an octane

enhancer of choice. A key factor in realizing that potential quickly would be acceptance of ethanol by a major integrated refiner/marketer.

Fuel ethanol is renewable, domestic motor fuel from corn. Ethanol's main attributes, when blended at a 10 percent level in gasoline, are that it reduces carbon monoxide emissions from 25 percent to 30 percent and that it increases octane rating by two to three points, making regular gasoline into premium.

The wet milling industry has also dramatically reduced the energy input in ethanol production. The latest published figures indicate the following energy equation for corn wet milling fuel ethanol production:

BTu/Gallon		
76,000	Ethanol	
	34,000	Processing
	18,598	Corn Production
52,598		Total Energy Input
23,402		Net Energy Gain

In addition to the net gain, processing energy is provided by coal or natural gas—abundant domestic fuels—to create ethanol which replaces imported crude oil.

Fuel Ethanol—HFCS Product Balance

Fuel ethanol production has gone from nothing in 1977 to over 900 million gallons projected for 1991, largely from corn wet milling.

ADM at its Decatur, Illinois, facility was the first CRA member to produce fuel ethanol. It added 50 million gallons or 20 million bushels per year of fermentation capacity to its existing wet milling plant producing HFCS. CPC, facing changing markets and large capital requirements at its Pekin, Illinois, facility, entered a joint venture with Texaco to convert the plant entirely to ethanol.

In the late 1970s, the A. E. Staley Manufacturing Company was considering the expansion of its HFCS production capacity with a new plant in Loudon, Tennessee. The plant was being constructed primarily to meet the growing demand for HFCS in the beverage industry. Coke and Pepsi had not yet completed their approval process for the substitution of HFCS for sucrose, and the wet milling industry was determined not to let capacity constraints be a factor in slowing that approval process.

As the planners assessed the market for HFCS, they were concerned about the seasonal fluctuations in demand for HFCS. A plant constructed solely for HFCS production would have to endure extended downtime or ship to uneconomic locations. The industry as a whole cannot ship more product in the fourth and first quarters, with 21 percent and 19 percent of demand respectively, than food and beverage processors will consume.

As the soft drink industry became a more important segment of consumption, this exaggerated the impact of seasonality. The summer peak, second and third quarters, required 60 percent of the HFCS and the new Tennessee plant had to be sized to meet that demand.

After extensive evaluation of product alternatives, the Staley board approved the new Loudon plant in February, 1980. It was the first "Greenfield" plant designed to incorporate both HFCS and ethanol. It was fully on-stream by winter of 1982.

The design of Loudon permitted Staley to swing production from HFCS to ethanol while maintaining corn grind at a stable level. Because more than 50 percent of the capital cost of a typical wet milling facility is in the grind

U.S. Per Capita Sweetener Consumption

Year	Refined Sugar	HFCS	Glucose	Dextrose	Total Corn Sweeteners	Honey and Edible Syrups	Total Caloric Sweeteners
			Pounds, dry basis				
1985	62.5	44.1	18.0	3.5	65.6	1.4	129.5
1986	59.7	45.9	18.0	3.5	67.4	1.4	128.5
1987	61.6	47.1	18.0	3.5	68.6	1.4	131.6
1988	61.6	47.8	18.0	3.6	69.4	1.4	132.4
1989*	61.9	48.0	18.3	3.6	69.9	1.4	133.2
1990**	62.6	48.3	18.7	3.8	70.8	1.3	134.7

*Preliminary
**Forecast
Source: USDA—Economic Research Service

or front end of the plant, maintaining grind at reasonably high levels keeps average costs down.

For example, Loudon's capacities are approximately as follows:

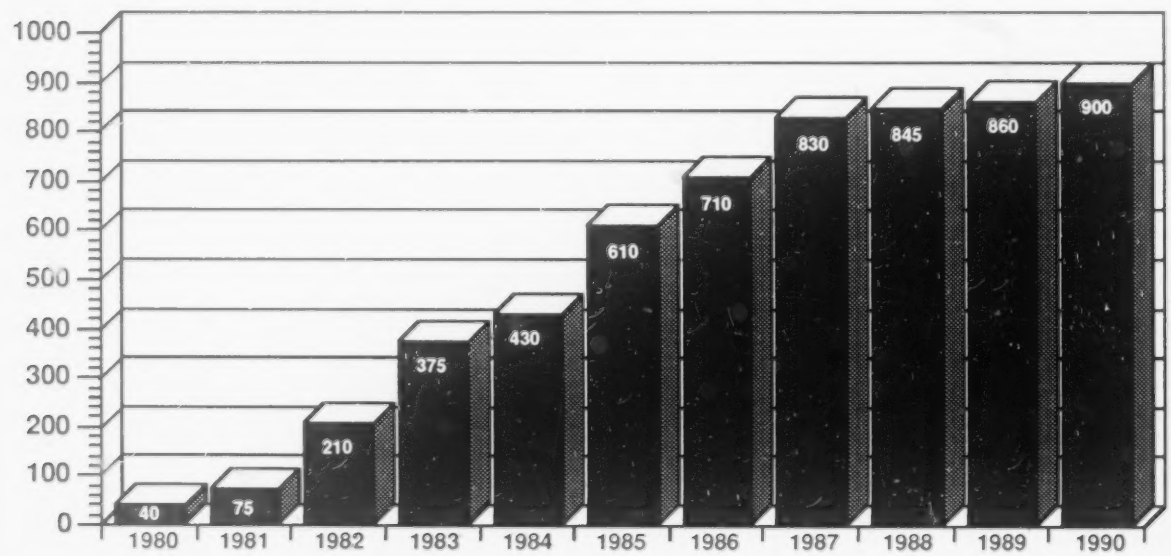
	Thousand Bushels per Day
Finishing Capacity	
HFCS	115
Ethanol	50
	165
Grind	115
Swing Capacity	50

In the fourth and first quarters, grind can be diverted from HFCS to ethanol. Although ethanol consumption is currently higher during the summer—a pattern similar to HFCS—it can be handled and stored much less expensively than HFCS. Ethanol's shelf-life is also almost indefinite.

HFCS demand, now over 12 billion pounds dry per year, continues to grow at a modest rate. Fuel ethanol production of 900 million gallons, primarily from corn wet milling, may experience dramatic growth given the new legislation.

Corn refiners will continue to improve the technology of manufacturing these products and continue to take advantage of the balance provided by ethanol production in what will remain a distinctly seasonal HFCS business. It is expected that more participants and more capacity for ethanol will be entering the market in the 1990s. The corn refiners will increasingly take advantage of the balancing effect of alcohol and HFCS production.

U.S. Ethanol Production, 1980 to 1990



Source: Renewable Fuels Association

Starch Chemistry Transforms Corn Into Gold

by Paul S. Smith
President, Paul Smith Associates

A few years ago, Kyd Brenner presented a paper to the Starch Technology Seminar at the Center for Professional Advancement in East Brunswick, New Jersey. In it, he stated that corn in the United States should be called "home-grown gold."

Today, more than ever before, we are seeing corn contribute even more by improving manufacturing efficiency, solving environmental problems and contributing to an over all improvement in living standards both in the United States and around the world. Truly, corn is becoming as valuable as gold.

From 1981 to 1989, corn growers in the U.S. harvested on average 7,211,000,000 bushels of corn per year, grown on over 66,000,000 acres. Per acre corn production increased: In seven of these years yield was greater than 106 bushels per acre. In 1988 yield reached a record 119.8 bushels per acre.

This increase in production—the result of the hard work of growers and scientists—has made the U.S. the premier corn producer in the world and has supplied U.S. corn refiners with a reliable source of their essential raw material.

At the same time, corn refining companies have made major commitments of time, money, personnel, research and marketing efforts to achieve a new generation of top quality products. These safe, nutritious and uniquely functional starch products today are aiding the U.S. manufacturing sector in many ways.

Some new starches are the result of long-term plant hybrid breeding programs, while others have been developed through enzymatic, mechanical or chemical treatments to common corn starch. Much of the latest research is based on the use of highly sophisticated biotechnological processes. During the next ten years many of these products will begin to reach the marketplace and continue to aid manufacturers to produce higher quality products that contribute to better living.

About 15 percent of the corn harvested in the United States is utilized to make carbohydrate products for use in food, textile, paper, corrugating, pharmaceutical, beverage and other industries. Where necessary, these products have undergone the stringent and expensive testing required by the Food and Drug Administration or other similar regulatory bodies.

Each product so approved has been a high-cost investment for the petitioning company. Such costs (research, development, testing and petitioning) are borne by companies with the belief that better starch products will become important value-added properties that fulfill consumers' needs and yield a reasonable margin of profit.

In the last 15 years, the U.S. food industry has continued its growth. By 1987 it was reported to be the number one U.S. industry with total shipments over $334 billion. Food processors purchase over $225 billion worth of ingredients for use in more than 22,000 plants, over 6,000 of them employing more than 50 people.

This represents a major opportunity for starch producers. Almost 4,000 individual items in a typical supermarket include ingredients made from corn, of which starch is one of the most essential. The food industry, like other manufacturing sectors, has faced ever increasing labor, power, packaging, regulatory, shipping and ingredient costs. One method that helps to stabilize costs is to use ingredients with more effective functional properties or to replace one ingredient with another lower cost ingredient. Many food companies have turned to corn processors to find the various types of starches that will achieve these goals.

One typical program involves the replacement of gum arabic. Approximately 15 years ago, a major drought struck the Sudan area of Africa, the region which grows the majority of gum arabic used in beverages, flavors, confections, sauces and various industrial applications. Scientists at several companies, including those at National

Starch and Chemical Company's technical center, developed special starch products to serve the functional needs in foods that had been filled by gum arabic.

Today, several types of modified starches, dextrins and maltodextrins are used by manufacturers as gum arabic replacers with a high degree of success. In fact, although the price of imported natural gums has declined, U.S. companies continue to use U.S. grown and processed modified starch or dextrin products because they offer high quality, are readily available, and are economical.

The starch industry is very sensitive to consumer needs. During the past ten years, American consumers, recognizing that good health is related to diet, have become more sophisticated about their food choices. Increasingly, they are reading labels and understanding the significance of cholesterol and saturated fats. Consumers now prefer products offering less or none of these undesirable components. Dietary weight reduction programs are also affecting the marketplace. It is estimated that over 25 percent of American adults spent over $35 billion in 1989 on special dietary foods and that the growth rate for this sector will be over ten percent per year through 1995.

In response, corn refiners have developed food starches that can replace fats in some foods, with better results Starches offer the following advantages:

- No cholesterol,
- Lower caloric value per gram,
- Less opportunity to deteriorate in storage,
- Easier to handle in manufacturing,
- Better consumer acceptance,
- More unique textural qualities.

Several starch manufacturing companies, including National Starch and Chemical Company, A.E. Staley Manufacturing Company, and American Maize-Products Company, have developed series of modified starches, dextrins or combination products to replace or reduce shortening in cake mixes, butterfat in frozen desserts, fat in chocolate syrups, and oils in pourable and spoonable dressings and in other sauces. Starches can also replace fats in some icings, confections and meat products such as hot dogs, hamburgers and formed loaves. More of these starches are becoming available and being used in consumer products in an effort to improve the American diet.

At the recent IFT Exposition, several starch companies demonstrated starch systems which have been especially designed to be used in microwave food products. These foods need starches with unique viscosity, heat and shear resistant properties to meet the requirements of microwave processing. This market is growing fast, with nearly 75 percent of U.S. households owning microwave ovens. Consumers want convenience and quality. These new

Corn: Supply and Disappearance

	Supply				Disappearance					Ending Stocks		
					Domestic Use							
Year beginning September 1	Beginning stocks	Production	Imports	Total	Food, alcohol and industrial	Seed	Feed and residual	Total	Exports	Total disappearance	Govt. owned	Privately owned	Total
					Million bushels								
1980/81	2,034.3	6,639.4	0.8	8,674.5	697.8	20.2	4,891.2	4,891.2	2,391.2	7,282.4	241.8	1,150.3	1,392.1
1981/82	1,392.1	8,118.7	0.5	9,511.3	777.8	19.4	4,180.8	4,978.0	1,996.7	6,974.7	280.1	2,256.5	2,536.6
1982/83	2,536.6	8,235.1	0.5	10,772.2	880.3	14.5	4,533.0	5,427.8	1,821.3	7,249.1	1,142.7	2,380.4	3,523.1
1983/84	3,523.1	4,174.3	1.7	7,699.1	956.0	19.1	3,831.3	4,806.4	1,886.4	6,692.8	201.5	804.8	1,006.3
1984/85	1,066.3	7,672.1	1.7	8,680.1	1,070.0	21.2	4,090.5	5,181.7	1,850.2	7,031.9	224.9	1,423.3	1,648.2
1985/86	1,648.2	8,875.5	9.9	10,533.6	1,140.0	19.5	4,107.3	5,266.8	1,227.3	6,494.1	545.7	3,493.8	4,039.5
1986/87	4,039.5	8,225.8	1.7	12,267.0	1,175.0	16.7	4,701.2	5,892.9	1,492.4	7,385.3	1,443.2	3,438.5	4,881.7
1987/88	4,881.7	7,131.3	3.4	12,016.4	1,212.0	17.2	4,811.7	6,040.9	1,716.4	7,757.3	835.0	3,424.1	4,259.1
1988/89	4,259.1	4,928.7	2.8	9,190.5	1,232.4	18.7	3,980.6	5,231.7	2,028.5	7,260.1	362.5	1,567.9	1,930.4
1989/90[1]/	1,930.4	7,525.5	1.9	9,457.8	1,271.0	19.0	4,454.6	5,744.6	2,368.8	8,113.3	233.0	1,111.5	1,344.5
1990/91[2]/	1,344.5	7,933.1	2.0	9,279.6	1,300.5	19.5	4,850.0	6,170.0	1,850.0	8,020.0	400.0	860.0	1,260.0

[1]/Preliminary [2]/Projected
Source: USDA

modified corn starches provide the proper qualities.

Today, we are confronted with news about the deteriorating environment and how industries must reduce air and water pollution. Over the years, corn refining companies have developed starch products that help paper manufacturers control environmental problems and, at the same time, increase production capability, improve product quality and reduce operating costs. The application of hydroxyethyl ether, cationic and amphoteric-type starches has improved machine drainage and reduced water pollution, allowed plants to run at a higher production rate, increased paper strength and resulted in higher quality end products at a lower cost.

For example, Penford Products Company developed a line of products, chemically classified as hydroxyethyl ether derivatives of corn, which can be varied to meet individual paper manufacturing plants' needs. Hydroxyethyl ether groups reduce the associated forces between the molecules to produce higher quality finished papers compared with those using unmodified corn, enzyme-converted corn or oxidized starches.

Hydroxyethyl ether-type starches are used as surface film-formers in size press operations and pigmented coating operations. In surface sizing, they tend to make a more effective film on the paper, reducing the tendency for materials like oil-based inks, grease, wax, varnish and lacquers to penetrate the paper. Ether-type starches can be used with latex emulsions as the adhesive in paper coatings and with synthetic latex cobinders to replace the protein or casein binders formerly used in high quality offset papers.

Cationic starches were developed by National Starch and Chemical Company as an answer to several major manufacturing needs such as:

- Stronger internal fiber binding system to yield better sheet strength,
- Better pigment retention during manufacture, so that less pigment is used and less is lost in waste water,
- Better water drainage from the paper, which increases manufacturing efficiency,
- Better starch retention.

These characteristics have become more important as paper plants have become bigger and production rates have increased. Improved starches have also played a role in efforts to reduce the loss of solubles into the water stream as one step in reducing water pollution.

Today, more and more higher quality paper is being used in magazines, computer paper, and fine writing goods, and the qualities given by cationic starches are needed more than ever. As cationic starches, with their "value added" qualities, replace oxidized and enzymatic converted products, they are contributing to paper industry efforts to control ingredient costs, reduce the quantity of solubles going into the water stream, improve the plant production efficiency and obtain products of higher quality.

Most recently, efforts to increase the effectiveness of cationic starches have led to a new generation of modified starches classified as amphoteric starches. These products, containing anionic groups as well as cationic groups on the starch molecules, offer improved properties when used under certain critical conditions where cationic starches may be limited. They open up new improved higher quality products.

A new field for starch technology is the development of starch-based degradable products to replace various petroleum-based plastics. While much research is still going on in this area, there are already exciting and important starch-based degradable products in use.

Just last November, National Starch and Chemical Company introduced ECO-FOAM™, a loose packing material to replace plastic "peanuts." ECO-FOAM, composed of 95 percent starch, is designed to dissolve in water. Because it is non-toxic and food safe, consumers can wash it down the drain or throw it on the lawn for the next rain to dissolve.

The starch industry has prospered by responding to the major problems facing its customers and the ultimate consumer. Starches now being developed will offer unique qualities to fulfill manufacturing and consumer demands for years ahead. Corn refiners will continue to apply the best in science to paper and food technologies so they can continue to supply the best products in the world.

"Home grown gold" is getting even brighter and better!

U.S. Corn for Grain: Yield and Production

State	Area Harvested			Yield			Production		
	1988	1989	1990	1988	1989	1990	1988	1989	1990
		1,000 Acres			*Bushels*			*1,000 Bushels*	
AL	170	180	240	44.0	81.0	58.0	7,480	14,580	13,920
AZ	13	13	7	155.0	145.0	160.0	2,015	1,885	1,120
AR	60	58	73	100.0	122.0	95.0	6,000	7,076	6,935
CA	187	185	160	145.0	160.0	160.0	27,115	29,600	25,600
CO	800	930	830	160.0	145.0	155.0	128,000	134,850	128,650
DE	140	133	172	70.0	100.0	115.0	9,800	13,300	19,780
FL	65	80	75	58.0	74.0	71.0	3,770	5,920	5,325
GA	500	550	550	62.0	95.0	68.0	31,000	52,250	37,400
ID	50	50	30	130.0	125.0	130.0	6,500	6,250	3,900
IL	9,600	10,750	10,400	73.0	123.0	127.0	700,800	1,322,250	1,320,800
IN	5,000	5,200	5,450	83.0	133.0	129.0	415,000	691,600	703,050
IA	10,700	12,250	12,400	84.0	118.0	126.0	898,800	1,445,500	1,562,400
KS	1,150	1,240	1,450	125.0	125.0	130.0	143,750	155,000	188,500
KY	1,100	1,180	1,200	73.0	116.0	100.0	80,300	136,880	120,000
LA	125	142	186	95.0	95.0	116.0	11,875	13,490	21,576
MD	420	400	450	65.0	110.0	118.0	27,300	44,000	53,100
MI	1,600	1,970	2,070	70.0	113.0	115.0	112,000	222,610	238,050
MN	4,700	5,600	6,150	74.0	125.0	124.0	347,800	700,000	762,600
MS	150	140	140	60.0	70.0	80.0	9,000	9,800	11,200
MO	2,020	2,290	1,960	76.0	96.0	105.0	153,520	219,840	205,800
MT	20	4	9	110.0	80.0	95.0	2,200	320	855
NE	6,600	7,000	7,300	124.0	121.0	128.0	818,400	847,000	934,400
NJ	79	71	75	70.0	102.0	118.0	5,530	7,242	8,850
NM	55	60	55	155.0	160.0	145.0	8,525	9,600	7,975
NY	540	570	620	85.0	93.0	98.0	45,900	53,010	60,760
NC	970	950	1,070	84.0	93.0	68.0	81,480	88,350	72,760
ND	380	465	460	58.0	75.0	80.0	22,040	34,875	36,800
OH	3,000	2,900	3,450	85.0	118.0	121.0	255,000	342,200	417,450
OK	72	78	88	95.0	120.0	114.0	6,840	9,360	10,032
OR	19	22	18	158.0	160.0	150.0	3,002	3,520	2,700
PA	910	960	970	65.0	103.0	113.0	59,150	98,880	109,610
SC	335	340	320	58.0	91.0	45.0	19,430	30,940	14,400
SD	2,400	2,650	3,000	55.0	72.0	78.0	132,000	190,800	234,000
TN	530	530	510	73.0	107.0	86.0	38,690	56,710	43,860
TX	1,350	1,400	1,450	96.0	106.0	90.0	129,600	148,400	130,500
UT	22	20	19	124.0	132.0	140.0	2,728	2,640	2,660
VA	295	365	365	79.0	110.0	100.0	23,305	40,150	36,500
WA	80	90	80	170.0	175.0	175.0	13,600	15,750	14,000
WV	40	46	50	58.0	95.0	105.0	2,320	4,370	5,250
WI	1,950	2,800	3,000	67.0	111.0	118.0	130,650	310,800	354,000
WY	53	41	50	122.0	95.0	120.0	6,466	3,895	6,000
US	58,250	64,703	66,952	84.6	116.3	118.5	4,928,681	7,525,493	7,933,068

Source: USDA

Corn Refiners Association, Inc.
1100 Connecticut Avenue, NW.
Washington, D.C. 20036
202 331-1634

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